JET JOURNAL of ENERGY TRANSITION

TYPE: Original article
PUBLISHED: December 29, 2023
DOI: 10.59264/jet.v1i1.33

*CORRESPONDENCE
Tsolmon Myagmarjav
E-mail address:
myagmarjav.tsolmon845@mail.kyutech.jp

RECEIVED: November 16, 2023
ACCEPTED: December 21, 2023
PUBLISHED: December 29, 2023

CITATION
T. Myagmarjav, T. Bandi, B.-E. Bayar, and S. Ohtsuka, "Change in Electric Power Consumption in Mongolia in 2020 and the Impact of the COVID-19 Pandemic", Journal of Energy Transition, vol. 1, no. 1, pp. 1–6, Dec. 2023.
https://doi.org/10.59264/jet.v1i1.33

Change in Electric Power Consumption in Mongolia in 2020 and the Impact of the COVID-19 Pandemic

Tsolmon Myagmarjav[1*], Tuvshinbayar Bandi[1], Bat-Erdene Bayar[2], Shinya Ohtsuka[1]

[1*](Department of Engineering, Kyushu Institute of Technology, Kitakyushu, Japan)

[2](School of Power Engineering, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia)

Abstract - This paper deals with the change in electric power (EP) consumption in Mongolia in 2020 based on data on the maximum and minimum EP consumption a day, provided by NPTG. The changes in EP consumption in Mongolia in detail as weekly or seasonal changes as well as the impact of the COVID-19 pandemic have not been clear, even though annual EP consumption was provided from the reports of the World Bank, IEA, and other international institutes as statistical data. Differences in the maximum average hourly and the minimum EP consumption in a day was 277 MWh (30.2%) and in the maximum and minimum daily EP consumption in 2020, which appeared in winter and summer, respectively, was 933 MWh (71.3%). Also, a 104-MWh (14.8%) drop was confirmed on special days like Naadam. To discuss the impact of COVID-19, the values of 2017 were used as a criterion for a year absent of a pandemic, and the stringency index, an indicator used to quantify the severity and stringency of government policies and measures, was introduced, and compared with the monthly EP consumption in 2020. The COVID-19 pandemic decreased the EP consumption of 40 MWh (2 to 6%) except in December due to the free-electricity policy. The EP consumption showed the dependency of the stringency index, particularly a clear drop over 50 of the index values. These new findings of EP consumption properties are expected to apply EP demand forecasting and make design plans for future EP systems in Mongolia.

Key words - Electric power consumption, Outside temperature, COVID-19, Stringency index

Монголын цахилгаан эрчим хүчний хэрэглээн дэх 2020 оны өөрчлөлт ба КОВИД-19 тахлын нөлөө

Мягмаржавын Цолмон[1*], Бандийн Түвшинбаяр[1], Баярын Бат-Эрдэнэ[2], Охцука Шиня[1]

[1*](Инженерийн Ахисан Түвшний Сургууль, Кюүшүгийн Технологийн Институт, Китакюүшү хот, Япон улс)

[2](Эрчим Хүчний Сургууль, Шинжлэх Ухаан Технологийн Их Сургууль, Улаанбаатар хот, Монгол улс)

Хураангуй - Дэлхийн банк, Олон улсны эрчим хүчний агентлаг болон бусад олон улсын байгууллагууд Монголын цахилгаан эрчим хүчний (ЦЭХ) хэрэглээний жил бүрийн тайланг гаргаж байсан боловч эдгээр тайланд Монгол орны онцлогтой уялдуулан байгаль цаг уурын өөр өөр орчин нөхцөлтэй жилийн дөрвөн улирал, долоо хоног тутмын ЦЭХ хэрэглээний өөрчлөлт, улмаар улс орны аж үйлдвэрлэл, ахуй амьдралд онцгой нөлөөлөл үзүүлсэн КОВИД-19 цар тахлын хөл хорионы үеийн ЦЭХ хэрэглээний онцлог өөрчлөлтүүдийг тодорхой тоон утгаар илэрхийлж тайлбарлаагүй байдаг. Иймээс бид Монгол улсын эрчим хүчний томоохон компани болох "Цахилгаан Дамжуулах Үндэсний Сүлжээ" ТӨХК-иас гаргасан 2020 оны Монгол улсын ЦЭХ хэрэглээний хоногийн их, бага ачааллын өгөгдлийг ашиглан жилийн дөрвөн улирал, долоо хоног тутмын ЦЭХ хэрэглээний өөрчлөлт болон КОВИД-19-ийн нөлөөллийг нарийвчлан судаллаа. 2020 оны хоногийн их, бага ЦЭХ хэрэглээний дундаж зөрүү нь 277 МВт/ц (30.2%), өвлийн их, зуны бага ЦЭХ хэрэглээний зөрүү 933 МВт/ц (71.3%) байна. Мөн наадам гэх мэт тэмдэглэлт өдрүүдэд ЦЭХ хэрэглээ 104 МВт/ц (14.8%) буурч байна. КОВИД-19 тахлын нөлөөллийг тодорхойлохын тулд 2020 оны сар бүрийн ЦЭХ хэрэглээний өөрчлөлтийг КОВИД-19-ийн нөлөөгүй жил болох 2017 оны утгуудтай харьцуулан, КОВИД-19 цар тахлын хөл хорионы үед Монгол улсын засгийн газраас гаргасан шийдвэрүүд болон хөл хориог тоон утгаар илэрхийлэх хөл хорионы индекстэй харьцуулах зарчим дээр үндэслэгдсэн болно. КОВИД-19 тахал нь 12 сараас бусад ЦЭХ хэрэглээг 40 МВ/ц (2-6%) хүртэл бууруулсан нь хөл хорионы индекс болон ЦЭХ хэрэглээний хамаарлаас илэрсэн. Ялангуяа хөл хорионы индексийн утга 50-аас дээш болоход ЦЭХ хэрэглээ буурсан нь илт байсан. Энэ үр дүнг ЦЭХ хэрэгцээг таамаглахад ашиглаж, ирээдүйн ЦЭХ системийн загварчлал, төлөвлөгөөнд тусгах болно.

Түлхүүр үг - Цахилгаан эрчим хүчний хэрэглээ, Гадна агаарын температур, КОВИД-19, Хөл хорионы индекс

JET JOURNAL of ENERGY TRANSITION
TYPE: Original article
PUBLISHED: December 29, 2023
DOI: 10.59264/jet.v1i1.33

I. Introduction

Mongolian electric power (EP) consumption is continuously increasing year by year [1], which corresponds to GDP and population growth [2]. It is well known EP consumption depends on not only economic conditions but also social activity and weather conditions [3]. Since there is a fact that EP demand is increasing and most of EP demand is supplied by coal-fired thermal power plants (TPP) in Mongolia, introducing renewable energy sources and expanding the EP system with higher reliability are expected [4]. Furthermore, the Mongolian EP system is vulnerable due to the slow response of TPP [5]. It is necessary to improve a sufficient, maneuverable EP generation for the EP system. Even though, Mongolian EP demand was performed with hourly resolution [6], weather dependence, sensitivity and social activity were not studied well. From this point of view, EP consumption properties in Mongolia should be clarified, especially changes in EP consumption in a day, a week, or a season. Also, local weather conditions should be observed and recorded with sufficient measurement intervals. These could contribute to improving EP forecasting technology in Mongolia.

In this study, the authors investigated EP consumption properties in Mongolia in 2020 based on the data provided by the Central Energy System (CES), officially named the National Power Transmission Grid State-Owned Joint Stock Company (NPTG), the largest energy system in Mongolian including the capital, Ulaanbaatar city, and temperature properties as most effective weather conditions [7], in view of the future EP demand forecasting and EP system planning. As an example of the local weather condition measurement, the authors discussed the system applicability and operation issues for the developed local weather measurement system consisting of a single-board computer, Raspberry Pi, and weather sensors, which was placed in the Mongolian University of Science and Technology (MUST) campus in Ulaanbaatar city, by comparing data between the measurement and the observed one by the National Agency for Meteorology and Environmental Monitoring (NAMEM) in Mongolia. In addition, since 2020 was a special year that was the COVID-19 pandemic, it was known that COVID-19 affected to social and economic activities. In this study, the impact of COVID-19 on EP consumption in Mongolia was investigated and discussed with a famous indicator proposed by Oxford University, *i.e.* the stringency index of the Oxford Covid-19 Government Response Tracker [8].

II. Method of Data Collections

A. Electric Power Consumptions

The hourly maximum and minimum EP consumption i.e., P_{max} and P_{min}, were recorded in a day in the NPTG. From these two values, the daily average P_{av} can be calculated by averaging the two values and the daily EP consumption by multiplying P_{av} by 24 hours. Note that this evaluation method to obtain the daily average and the daily EP consumptions from the two values was simple but new trial and confirmed validity from the data on the 10 Japanese EP companies with less than 2% accuracy, especially with 0.25% accuracy on data from the Hokkaido EP company which is placed in the northern part of Japan and is most similar to Mongolia.

B. Weather Conditions

The daily average temperature T_{av} was recorded in the NAMEM in Mongolia. In this study, the temperature in Ulaanbaatar city was used as the representative one to discuss the EP consumption properties.

Fig. 1 shows the configuration of the local weather measurement system, which consists of the Raspberry Pi model 3B (main body), weather sensors, and Twe-lite DIPs that enable wireless data transmission and reception between the main body and sensors. The sensor (BME-280) can measure not only temperature but also relative humidity and atmospheric pressure. The system was placed on the campus of the MUST to measure the local campus weather conditions. The main body was placed in the laboratory room, while the sensor part was placed outside to measure the outside weather conditions at first to verify the operation performance and the measured data was transferred wirelessly to the main body with the Twe-lite DIP. The recorded data by the main body were transferred to the cloud system with Wi-Fi communication, which allows us to access the data from abroad regardless of the system location.

III. Results and Discussions

A. Seasonal Changes in EP Consumption in 2020

Fig. 2 shows changes in P_{max}, P_{min}, and P_{av} in Mongolia based on the NPTG data in 2020, including the COVID-19 pandemic period. This figure indicates that EP consumption in Mongolia peaks in winter and is low in summer, and there are many small oscillations and relatively larger spikes, numbered from 1 to 6. Also, changes in P_{max}, P_{min} and P_{av} seem to be similar. As shown in Figs. 2 (a) and (b) on P_{max}, there were special days showing relatively larger spikes as the numbers of 2, 3 and 4 *i.e., a* larger change in EP consumption about 100 MWh (12.5 %). It was confirmed that these days correspond to special national events and social events. Thus, these results

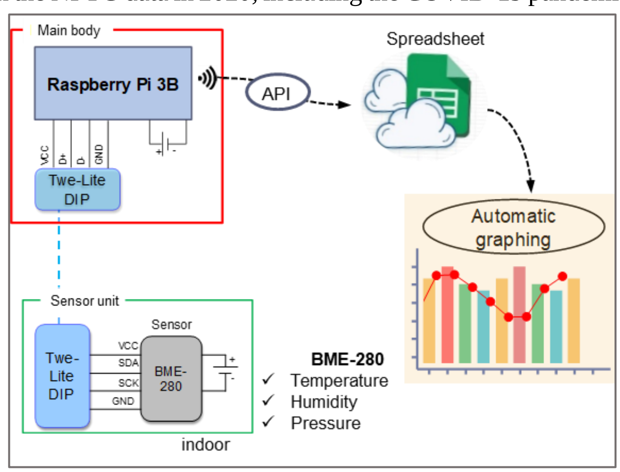
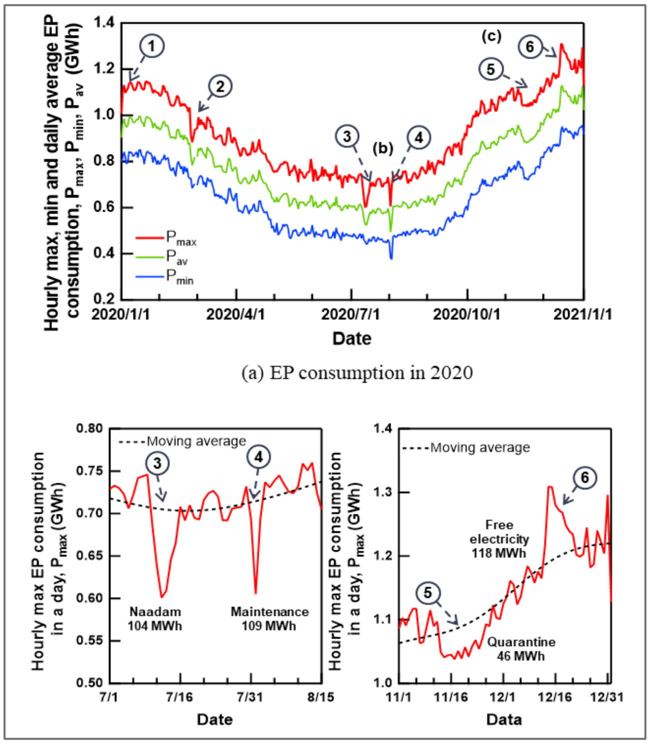


Figure 1. Developed local weather measurement system configuration

TYPE: Original article
PUBLISHED: December 29, 2023
DOI: 10.59264/jet.v1i1.33



(a) EP consumption in 2020

(b) Special days in summer (c) Special days in winter

Figure 2. Daily EP consumption in Mongolia

revealed how much and when EP consumption changed, which is important for future EP demand forecasting. These features will be discussed later further.

Fig. 3 shows the measured daily average temperature T_{av} in Ulaanbaatar city in 2020. The temperature appeared to vary between -20 ºC and 20 ºC symmetrically because the average temperature indicated by the dotted line was near 0 ºC. Note

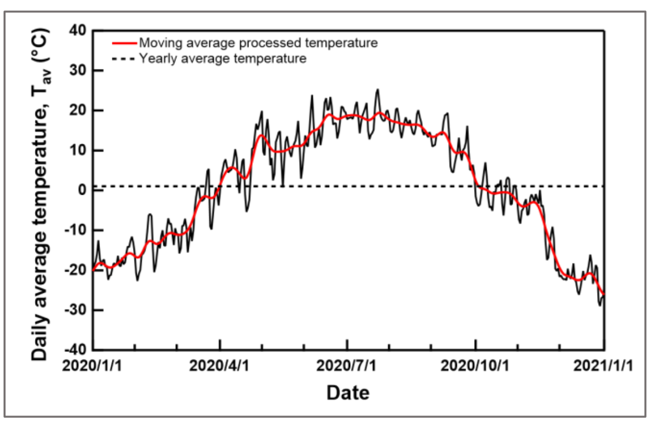


Figure 3. Change in daily average temperature in Ulaanbaatar in 2020

that the maximum temperature was +25.4 ºC recorded on July 23, and the minimum one was -29ºC on December 29, 2020. This knowledge of temperature properties also becomes important basic data for EP demand forecasting.

Fig. 4 shows an example of the measurement result of the temperature in the MUST campus by the developed local weather measurement system. Note that this measurement result was obtained from June 19, 2021, to January 1, 2023, which was not in the year 2020, and that the location of the sensor part was changed from the outdoor to indoor condition on November 18, 2021, due to the winter and summer temperature problem. That is, during the outdoor measurement, the measured temperature was remarkably changed in a day, and temperatures in summer were measured over 30 °C, *e.g.* there were results reaching near 50 °C, while in winter the lower limit of -10 °C, not decrease further. These values were quite different from the data of NAMEM as shown in Fig.3. This seemed to be attributed to influences of the sensor container in summer and the lower sensor operation temperature in winter. Namely, the measured higher temperatures over 30°C in summer could be caused by abruptly increased temperature around the sensor in the morning because the sensor was installed in a simple plastic container with small holes to avoid the rain and dust and the strong morning sunlight hit the container, while the measured lower limit of -10 °C in winter could be caused by sensor operation temperature in such cold condition even though the sensor and the Twe-lite DIP can be operated down to -30 °C according to the catalog specification. After changing the sensor location into the indoor condition, the remarkable change in temperature in a day disappeared. Like these experimental results, the operation issues in the actual use of the local weather measurement system in Mongolia were identified, and the applicably of the system was indicated as in Fig.4. Note that showed temperature properties only, but humidity and atmospheric pressure properties were also measured in this system. The details will be introduced in the next paper.

B. *Difference in daily EP consumption between weekdays and weekends*

Fig.5 shows the comparison of the average daily EP consumption for each day of the week in 2020, divided into

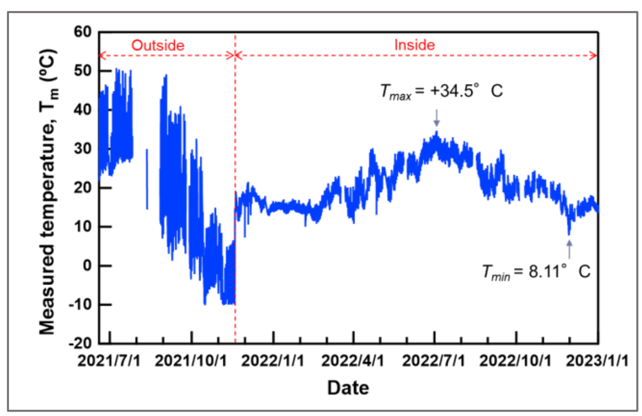


Figure 4. Example of the measured temperature in the MUST campus as the local weather data by the Raspberry Pi sensor system

TYPE: Original article
PUBLISHED: December 29, 2023
DOI: 10.59264/jet.v1i1.33

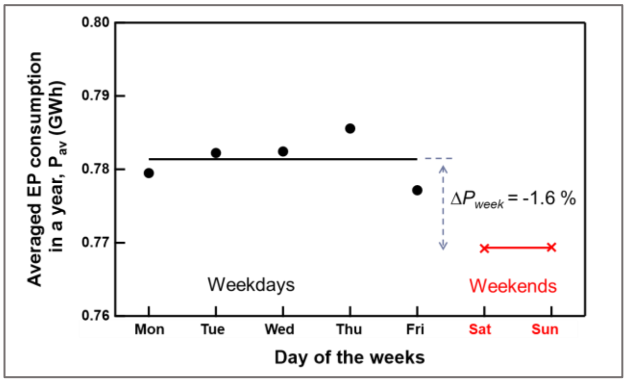


Figure 5. Difference in EP consumption on day of weeks

weekdays and weekends. This result is very important because it provides the basic data for forecasting EP consumption in Mongolia. The difference in the average daily EP consumption between the weekdays and weekends appeared, but it was not significant; the daily EP consumption on the weekends was about 1.6% lower than on the weekdays. This difference was much smaller than Japanese results, e.g. 18% in Chubu EP company, and can be interpreted as Mongolian main EP demand coming from mining and construction industries that operate continuously regardless of weekends. This result implies that the distinction between weekdays and weekends was less important for forecasting EP demand in Mongolia (compared to Japan).

C. *Difference between maximum and minimum EP consumption*

The differences between maximum and minimum EP consumption in a day, ΔP, were investigated based on the result in Fig.2 (a). Fig.6 shows the result. The changes in ΔP seems to be almost constant with a value of about 280 MWh, but several relatively larger spikes appeared, which corresponded to the special day's spikes shown in Fig.2. These

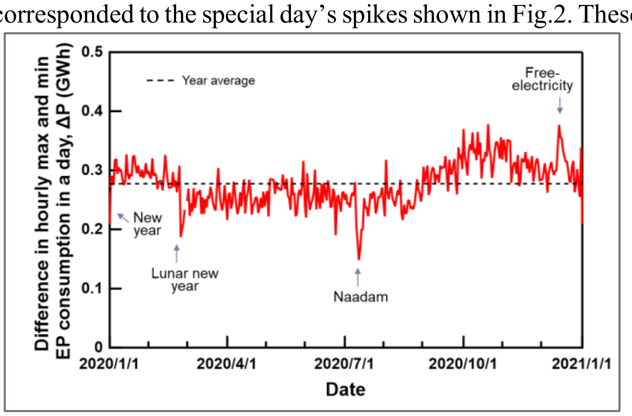


Figure 6. Changes in the difference between max, min EP consumption in a day

days were (1) New Year, (2) Lunar New Year, (3) National traditional day, so-called Naadam, and (5) Quarantine. Note that a larger positive spike of (6) corresponds to free electricity measures implemented as a government policy. The results from Fig.2 and Fig.6 give some important information on the change in EP consumption in a day and in a year as which the daily EP consumption change is about 300 MWh and the yearly EP consumption change is about 700 MWh, indicating the need to supply this amount of electricity for the reliable operation of the EP system in Mongolia. Note that long-term 4-year results from 2017 to 2020 and those temperature dependencies will be reported in the next paper in detail.

D. *Impact of COVID-19 pandemic*

The Stringency index is an indicator used to quantify the strictness or severity of government policies and measures, typically in the context of public health and crisis management, such as during a pandemic. This index taking values 0 to 100 is proposed by Oxford University as an index of the Oxford Covid-19 Government Response Tracker that systematically collects information on each government's response to the pandemic for 20 indicators, including school closures, and travel restrictions, and so on, and it should be noted that these indices are intended to document the severity of government policies, not to score the adequacy or effectiveness of government measures. Namely, a high index does not necessarily mean that a country's response is "better" than that of other countries.

Fig. 7 shows an example of changes in the Stringency index of Mongolia, Japan, the USA, and China for the COVID-19 pandemic period. The Mongolian Stringency index is similarly high as China's and the USA's, while Japan had a strictness of about 40. Mongolian index increased on January 27, closing the border with China and then closing the land and air border with all countries except residents on January 30. On the same day, the government closed schools. The first case transported from foreign countries were registered on March 10. The stringency index reached 80 at the end of May, but it loosened during the summer and autumn. On November 10, the first internal infection was detected, at which point all residents were quarantined for a

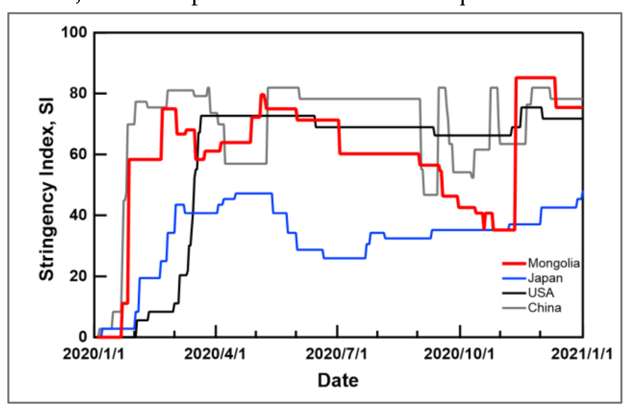


Figure 7. Change in Stringency index that is an index of the Oxford COVID-19 government response tracker in 2020 for four countries

month. After the one-month full quarantine, the government reduced it and started to pay the cost of energy consumption to all citizens, *i.e.* so-called "free-electricity" policy.

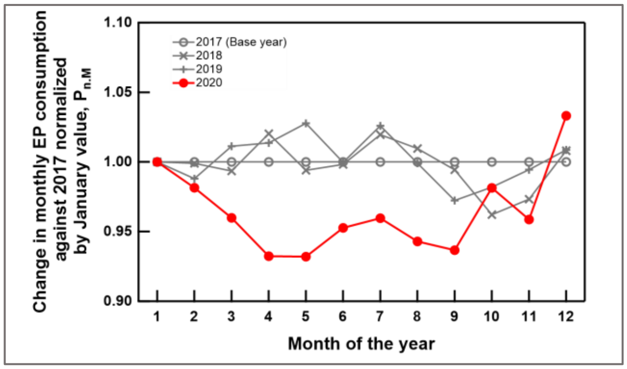


Figure 8. Change in the monthly EP consumption in 2020 normalized by the January values to indicate the COVID-19 impact EP consumption

Fig. 8 shows the change in monthly EP consumption in 2020 against the values of 2017 as a criterion of no influence year of the COVID-19 pandemic, which was normalized with January value, and the results for 2018 and 2019 against 2017 were also shown in Fig.8 for comparison. Note that a significant drop in the monthly EP consumption in 2020 was found, that is, a 2 to 6 % drop from February to September as the impact of the COVID-19 pandemic. The drops in October and November seemed not to be only related to the COVID-19 impact because of the appearance of similar drops in 2018 and 2019 that would include other reasons as weather conditions. Thus, since the impact of the COVID-19 pandemic on EP consumption in Mongolia was clarified quantitatively in Fig.8, the relationship between the Stringency index and change in EP consumption in Mongolia is first discussed in this paper.

In Fig.9, the relationship between the Stringency index and the changes in the monthly EP consumption in 2020 against 2017 shown in Fig.8 were summarized. As clearly seen in Fig.9, the monthly EP consumption showed a relation with the Stringency index which decreased with an increase in the Stringency index, particularly clear over 50 of the index value.

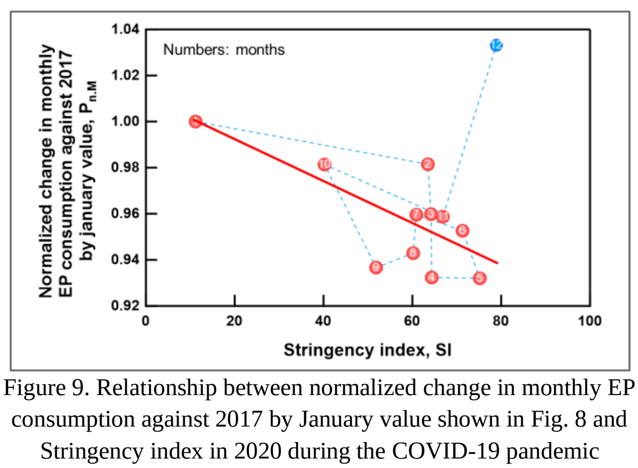


Figure 9. Relationship between normalized change in monthly EP consumption against 2017 by January value shown in Fig. 8 and Stringency index in 2020 during the COVID-19 pandemic

Note that only the December value was above 1, *i.e.* increment of the EP consumption in December, even in the index showing the higher value as 80, which might be due to the free-electricity policy. Thus, this result suggests that the Stringency index can be used as an indicator reflecting social serious conditions to forecast the electric power demand if necessary.

IV. CONCLUSIONS

The authors investigated electric power (EP) consumption properties and temperature properties in Mongolia in 2020 when the COVID-19 pandemic impacted social life together with the system applicability and operation issues for the developed local weather measurement system, in view of the future EP demand forecasting and EP system planning. As a result, features and changes in EP consumption properties in Mongolia were made clear. Namely, it revealed that the peak demand appeared in winter and the differences in the average hourly maximum and minimum EP consumption in a day was 377 MWh (29%), and in the maximum and minimum daily EP consumption in 2020 was 277 MWh (30%). Also, 104 MWh (15%) drop was confirmed on the special days as Naadam. Also, from the application result in the actual weather conditions, the operation issues and the applicability of the local weather measurement system, which consists of Raspberry Pi and the weather sensor, placed on the MUST campus were identified in this study. These new findings are expected to apply EP demand forecasting and make design plans for future EP systems in Mongolia.

ACKNOWLEDGMENT

This work is supported by the Mongolia-Japan Higher Engineering Education Development (M-JEED) project.

REFERENCES

1. “Statistics on Energy Performance 2020,” Mongolian Energy Regulatory Commission, Ulaanbaatar, Mongolia, 2021.
2. D. Sanchez, U. Batmunkh, D. Enkhtuya, A. Twum, “Mongolia Economic Update - Robust but Unbalanced Growth,” World Bank Group, Washington, D.C., USA, Rep. 186065, Nov. 2023.
3. Ching-Lai Hor, S. J. Watson and S. Majithia, “Analyzing the impact of weather variables on monthly electricity demand,” in IEEE Trans. on Power Syst.., vol. 20, no. 4, pp. 2078-2085, Nov. 2005, doi: 10.1109/TPWRS.2005.857397.
4. Z. Gansukh, “Mongol Dream Beyond Fossil Fuel: Prosperity of Greenification,” Elsevier, Renewable Energy, Vol. 171, 2021, pp. 95-102. https://doi.org/10.1016/j.renene.2021.02.079.
5. C. Adiyabazar, F. Gonzalez-Longatt, M. N. Acosta, J. L. Rueda and P. Palensky, “Assessment of Under-Frequency Load Shedding in Mongolia Considering Inertia Scenarios,” *2020 IEEE PES Innovative Smart Grid Technol. Europe (ISGT-Europe)*, The Hague, Netherlands, 2020, pp. 1201-1205, doi: 10.1109/ISGT-Europe47291.2020.9248837.
6. T. Osgonbaatar, et al., “A Rank Analysis and Ensemble Machine Learning Model for Load Forecasting in the Nodes of the Central Mongolian Power System,” MDPI Inventions, Vol. 8, 114. 2023, p. 1-20, https://doi.org/10.3390/inventions8050114
7. T. Myagmarjav, T. Bandi, B. E. Bayar and S. Ohtsuka, "Changes in Electric Power Demands of Mongolian and Japanese Local Areas in 2020 and Discussion on Seasonal Electricity Usage

TYPE: Original article
PUBLISHED: December 29, 2023
DOI: 10.59264/jet.v1i1.33

Based on the Temperature Dependence," 2022 9th International Conference on Condition Monitoring and Diagnosis (CMD), Kitakyushu, Japan, 2022, pp. 355-359, doi: 10.23919/CMD54214.2022.9991573

8. COVID-19 government response tracker, 2020 to 2009 [online] Available: https://www.bsg.ox.ac.uk/research/covid-19-government-response-tracker.

Зохиогчид

Tsolmon Myagmarjav

He received B.S. and M.S. degrees in electrical engineering from the Mongolian University of Science and Technology (MUST), Ulaanbaatar, Mongolia in 2015 and 2017, respectively. He is currently participating in a Ph.D. degree in Electrical Engineering in Ohtsuka lab at Kyushu Institute of Technology, Japan, and is supported by the Mongolia-Japan Higher Engineering Education Development project (MJEED) as a doctor scholarship.

He has been involved in research on industrial automation, electric power demand forecasting, and EM wave detection from smartphones. He is a student member of the IEEE and IEEJ.

Tuvshinbayar Bandi

He received a B.S. and M.S. degrees in electrical engineering from the Mongolian University of Science and Technology (MUST), Mongolia, in 2013 and 2016, respectively, and a Ph.D. degree in electrical and electronic engineering from Kyushu Institute of Technology (Kyutech), Japan, in 2022. From 2016 to 2017, he was an officer of scientific research and innovation in the MUST. Since 2018, he has been an assistant professor in the Department of Electrical Techniques, MUST. He is currently a Research Fellow with the Department of Electrical Engineering and Electronics, Kyutech. He has been involved in research on relay protection of electric power systems, insulation diagnostic for high voltage equipment, especially partial discharge detection, the UHF method and UHF sensors, EMC, and electromagnetic wave propagation and analysis. Dr. Bandi is a member of the IEEE and IEEJ.

Bat-Erdene Bayar

He received a B.S., and M.S. degrees in electrical engineering from the Mongolian University of Science and Technology (MUST), Mongolia, in 1994 and 1996, respectively, and a Ph.D. degree in National Research University Moscow Power Engineering Institute (NRU MPEI), Russia, in 2005. Dr. Bat-Erdene Bayar has been a dean of the Power Engineering School in MUST since 2021. He has been involved in research a relay protection and automation, especially the fault detection of transmission lines and power system planning.

Shinya Ohtsuka

He received the B.S., M.S. and Dr. Eng. degrees in Electrical Engineering from Kyushu University in 1994, 1996 and 1998, respectively, and was a Research Fellow of the JSPS from 1996 to 1998. Presently, he is a Professor at Kyushu Institute of Technology, Japan. He has been engaged in researches on the high voltage and discharge phenomena, especially partial discharges, breakdown and ESD, diagnostic and visualization technologies, EMC, lightning test for CFRP composite, and EM noise from power devices. Dr. Ohtsuka is a member of the IEEE, CIGRE, IEEJ, IEEDJ, and SAE AE2.